

# **EXHIBIT N**

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# Internet protocol suite

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(Redirected from Internet Protocols)

The **Internet protocol suite** is the set of communications protocols that implement the protocol stack on which the Internet and most commercial networks run. It has also been referred to as the TCP/IP protocol suite, which is named after two of the most important protocols in it: the Transmission Control Protocol (TCP) and the Internet Protocol (IP), which

## The five-layer TCP/IP model

### 5. Application layer

DHCP \* DNS \* FTP \* Gopher \* HTTP \* IMAP4 \* IRC \* NNTP \* XMPP \* POP3 \* SIP \* SMTP \* SNMP \* SSH \* TELNET \* RPC \* RTP \* RTCP \* RTSP \* TLS/SSL \* SDP \* SOAP \* BGP \* PPTP \* L2TP \* GTP \* STUN \* NTP \* ...

### 4. Transport layer

TCP \* UDP \* DCCP \* SCTP \* RSVP \* ...

### 3. Internet Layer

IP (IPv4 \* IPv6) \* IGMP \* ICMP \* OSPF \* ISIS \* IPsec \* ARP \* RARP \* RIP \* ...

### 2. Data link layer

802.11 \* ATM \* DTM \* Token Ring \* Ethernet \* FDDI \* Frame Relay \* GPRS \* EVDO \* HSPA \* HDLC \* PPP \* ...

### 1. Physical layer

Ethernet physical layer \* ISDN \* Modems \* PLC \* SONET/SDH \* G.709 \* Optical Fiber \* WiFi \* WiMAX \* Coaxial Cable \* Twisted Pair \* ...

were also the first two networking protocols defined. Today's IP networking represents a synthesis of two developments that began in the 1970s, namely LANs (Local Area Networks) and the Internet, both of which have revolutionized computing.

The Internet protocol suite — like many protocol suites — can be viewed as a set of layers. Each layer solves a set of problems involving the transmission of data, and provides a well-defined service to the upper layer protocols based on using services from some lower layers. Upper layers are logically closer to the user and deal with more abstract data, relying on lower layer protocols to translate data into forms that can eventually be

physically transmitted. The original TCP/IP reference model consists of 4 layers<sup>[1]</sup>, but is now viewed by many[1]

(<http://www.cisco.com/univercd/cc/td/doc/product/iaabu/centri4/user/scf4ap1.htm>) [2]

(<http://www.cacs.louisiana.edu/~mgr/404/burks/pcinfo/hardware/ethernet/tcpip.htm>) [3]

([http://www.et.put.poznan.pl/tcpip/architecture/archi\\_layers.htm](http://www.et.put.poznan.pl/tcpip/architecture/archi_layers.htm)) as a **5-layer model**. No IETF standards-track document has accepted a five-layer model, and IETF documents indeed deprecate strict layering of all sorts. Given the lack of acceptance of the five-layer model by the body with technical responsibility for the protocol suite, it is not unreasonable to regard five-layer presentations as teaching aids, possibly to make the IP suite architecture more familiar to those students who were first exposed to OSI layering.

## The OSI model

describes a fixed, seven-layer stack for networking protocols. Comparisons between the OSI model and TCP/IP can give further insight into the significance of the components of the IP suite. Both the OSI and the TCP/IP models are 'standards' and application developers will often implement solutions without strict adherence to proposed 'division' of labour within the standard whilst providing for functionality within the application suite. This separation of 'practice' from theory often leads to confusion, although it may also lead to more efficient implementation.

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## History

The Internet protocol suite came from work done by DARPA in the early 1970s. After building the pioneering ARPANET, DARPA started work on a number of other data transmission technologies. In 1972, Robert E. Kahn was hired at the DARPA Information Processing Technology Office, where he worked on both satellite packet networks and ground-based radio packet networks, and recognized the value of being able to communicate across them. In the spring of 1973, Vinton Cerf, the developer of the existing ARPANET Network Control Program (NCP) protocol, joined Kahn to work on open-architecture interconnection models with the goal of designing the next protocol for the ARPANET.

By the summer of 1973, Kahn and Cerf had soon worked out a fundamental reformulation, where the differences between network protocols were hidden by using a common internetwork protocol, and instead of the network being responsible for reliability, as in the ARPANET, the hosts became responsible. (Cerf credits Hubert Zimmerman and Louis Pouzin [designer of the CYCLADES network] with important influences on this design.)

With the role of the network reduced to the bare minimum, it became possible to join almost any networks together, no matter what their characteristics were, thereby solving Kahn's initial problem. (One popular saying has it that TCP/IP, the eventual product of Cerf and Kahn's work, will run over "two tin cans and a string", and it has in fact been implemented using homing pigeons.) A computer called a *gateway* (later changed to *router* to avoid confusion with other types of *gateway*) is provided with an interface to each network, and forwards packets back and forth between them.

The idea was worked out in more detailed form by Cerf's networking research group at Stanford in the 1973–74 period, resulting in the first TCP specification, RFC 675 (<http://www.ietf.org/rfc/rfc0675.txt>). (The early networking work at Xerox PARC, which produced the PARC Universal Packet protocol suite, much of which was contemporaneous, was also a significant technical influence; people moved between the two.)

DARPA then contracted with BBN Technologies, Stanford University, and the University College London to develop operational versions of the protocol on different hardware platforms. Four versions were developed: TCP v1, TCP v2, a split into TCP v3 and IP v3 in the spring of 1978, and then stability with TCP/IP v4 — the standard protocol still in use on the Internet today.

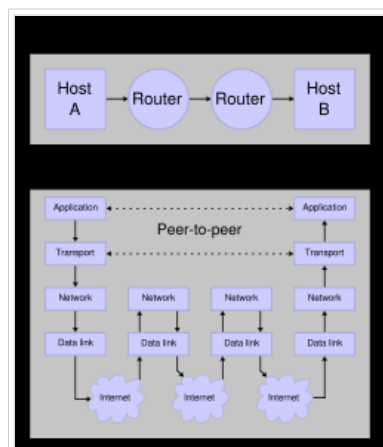
In 1975, a two-network TCP/IP communications test was performed between Stanford and University College London (UCL). In November, 1977, a three-network TCP/IP test was conducted between the U.S., UK, and Norway. Between 1978 and 1983, several other TCP/IP prototypes were developed at multiple research centres. A full switchover to TCP/IP on the ARPANET took place January 1, 1983.<sup>[2]</sup>

In March 1982, the US Department of Defense made TCP/IP the standard for all military computer networking.<sup>[3]</sup> In 1985, the Internet Architecture Board

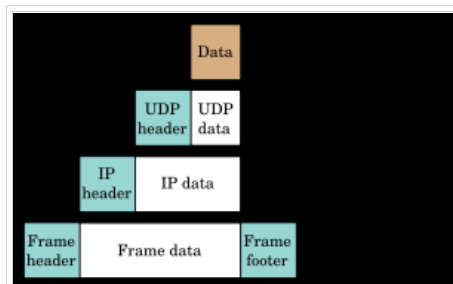
held a three day workshop on TCP/IP for the computer industry, attended by 250 vendor representatives, helping popularize the protocol and leading to its increasing commercial use.

On November 9, 2005 Kahn and Cerf were presented with the Presidential Medal of Freedom for their contribution to American culture.<sup>[3]</sup>

## Layers in the Internet protocol suite stack



IP suite stack showing the physical network connection of two hosts via two routers and the corresponding layers used at each hop



Sample encapsulation of data within a UDP datagram within an IP packet

The IP suite uses encapsulation to provide abstraction of protocols and services. Generally a protocol at a higher level uses a protocol at a lower level to help accomplish its aims. The

Internet protocol stack can be roughly fitted to the four layers of the original TCP/IP model:

<b>4. Application</b>	DNS, TFTP, TLS/SSL, FTP, Gopher, HTTP, IMAP, IRC, NNTP, POP3, SIP, SMTP, SNMP, SSH, TELNET, ECHO, BitTorrent, RTP, PNRP, rlogin, ENRP, ...
	Routing protocols like BGP, which for a variety of reasons run over TCP, may also be considered part of the application or network layer.
<b>3. Transport</b>	TCP, UDP, DCCP, SCTP, IL, RUDP, ...
<b>2. Internet</b>	Routing protocols like OSPF, which run over IP, are also to be considered part of the network layer, as they provide path selection. ICMP and IGMP run over IP and are considered part of the network layer, as they provide control information.
	IP (IPv4, IPv6)
	ARP and RARP operate underneath IP but above the link layer so they belong somewhere in between.
<b>1. Network access</b>	Ethernet, Wi-Fi, token ring, PPP, SLIP, FDDI, ATM, Frame Relay, SMDS, ...

.. In many modern textbooks, this model has evolved into the seven layer OSI Model, where the **Network access layer** is split into a Data link layer on top of a Physical layer, and the **Internet layer** is called Network layer.

## Implementations

Today, most commercial operating systems include and install the TCP/IP stack by default. For most users, there is no need to look for implementations. TCP/IP is included in all commercial Unix systems, Mac OS X, and all free-software Unix-like systems such as Linux distributions and BSD systems, as well as Microsoft Windows.

Unique implementations include Lightweight TCP/IP, an open source stack designed for embedded systems and KA9Q NOS, a stack and associated protocols for amateur packet radio systems and personal computers connected via serial lines.

## See also

- OSI Model
- TCP/IP model
- List of TCP and UDP port numbers
- IETF

## Notes

- ↑ Requirements for Internet Hosts -- Communication Layers (<http://www.isi.edu/in-notes/rfc1122.txt>) ,RFC 1122,R. Braden, October 1989
- ↑ Internet History (<http://www.livinginternet.com/i/ii.htm>)
- ↑ Ronda Hauben. From the ARPANET to the Internet ([http://www.columbia.edu/~rh120/other/tcpdigest\\_paper.txt](http://www.columbia.edu/~rh120/other/tcpdigest_paper.txt)) . TCP Digest (UUCP). Retrieved on 2007-07-05.

## References

- Internet History (<http://www.livinginternet.com/i/ii.htm>) -- Pages on Robert Kahn, Vinton Cerf, and TCP/IP (reviewed by Cerf and Kahn).
- Forouzan, Behrouz A. (2003). *TCP/IP Protocol Suite*, 2nd, McGraw-Hill. ISBN 0-07-246060-1.

## Further reading

- Andrew S. Tanenbaum. Computer Networks. ISBN 0-13-066102-3
- Douglas E. Comer. Internetworking with TCP/IP - Principles, Protocols and Architecture. ISBN 86-7991-142-9
- Joseph G. Davies and Thomas F. Lee. Microsoft Windows Server 2003 TCP/IP Protocols and Services. ISBN 0-7356-1291-9
- Craig Hunt TCP/IP Network Administration. O'Reilly (1998) ISBN 1-56592-322-7
- W. Richard Stevens. The Protocols (TCP/IP Illustrated, Volume 1). Addison-Wesley Professional; 1st edition (December 31, 1993). ISBN 0-201-63346-9
- Ian McLean. Windows(R) 2000 TCP/IP Black Book ISBN 1-57610-687-X

## External links

- RFC 675 (<http://www.ietf.org/rfc/rfc0675.txt>) - Specification of Internet Transmission Control Program, December 1974 Version
- TCP/IP State Transition Diagram ([http://www.night-ray.com/TCPIP\\_State\\_Transition\\_Diagram.pdf](http://www.night-ray.com/TCPIP_State_Transition_Diagram.pdf)) (PDF)
- RFC 1180 A TCP/IP Tutorial - from the Internet Engineering Task Force (January 1991)
- TCP/IP FAQ (<http://www.itprc.com/tcpipfaq/>)
- The TCP/IP Guide (<http://www.tcpipguide.com/free/>) - A comprehensive look at the protocols and the procedures/processes involved

- A Study of the ARPANET TCP/IP Digest ([http://www.columbia.edu/~rh120/other/tcpdigest\\_paper.txt](http://www.columbia.edu/~rh120/other/tcpdigest_paper.txt))
- TCP/IP Sequence Diagrams (<http://www.eventhelix.com/RealtimeMantra/Networking/>)
- The Internet in Practice (<http://www.searchandgo.com/articles/internet/internet-practice-4.php>)
- TCP/IP - Directory & Informational Resource (<http://softtechinfo.com/network/tcpip.html>)
- Daryl's TCP/IP Primer (<http://www.ipprimer.com>) - Intro to TCP/IP LAN administration, conversational style

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